Section 3
Exposure Assessment

Exposure assessment evaluates sources of contaminants in the API/PC/KR site, transport of contaminants to areas with human activity, and exposure to contaminants in these areas via inhalation, ingestion, and dermal contact. Whether an exposure occurs, and its magnitude and nature, depend on characteristics of the site. In this section, the character of the API/PC/KR site is described with a focus on those aspects most important for evaluating possible exposure to PCBs (Section 3.1). Subsequently, the potential for various exposure pathways[1] to cause human health impacts are analyzed, and means to quantitatively estimate health risks and hazards are developed.

3.1 Site Description

The API/PC/KR site is located in a moderately densely populated area. The site is located within the floodplain of the Kalamazoo River, a Class A water body and used for swimming, boating, and fishing. No restrictions against development along the river exist for areas outside of the 100-year floodplain. Land use along the river includes urban commercial and industrial; urban, suburban, and rural residential; agricultural; and recreational (MDPH 1991).

In addition to fishing and boating, recreational activities identified by the MDNR along the Kalamazoo River include:

- Canoeing
- Picnicking
- Mushroom and berry picking
- Wild food gathering
- Sightseeing/wild animal observation
- Bird watching

The primary source of contamination at the site is PCB residuals that were discharged into the river system by several paper mill facilities located upstream. In the de-inking phase of recycling paper fibers, specialty inks containing PCBs were liberated. Much of the dewatered paper waste was disposed of in landfills and sludge disposal areas located on the banks of the river. Erosion from these facilities, as well as direct discharge of millions of gallons per day of effluent into the river, has resulted in an estimated mass of over 29,300 kg of PCBs in instream sediments, and 24,500 kg of PCBs in exposed sediments at three former improvements (BB&L 2000).

The site contains six dams, three of which are owned by the MDNR and three that are owned by municipalities and private entities. These dams (in a downstream order)

[1] An exposure pathway consists of a source of contamination, a release/transport mechanism, a point of contact with contamination, and a route of exposure (inhalation, ingestion, or dermal contact) (see Section 3.2).

are: Plainwell Dam, Otsego City Dam, Otsego Dam, Trowbridge Dam, Allegan City Dam, and Caulkins Dam on Lake Allegan. The Plainwell, Otsego, and Trowbridge dams are the three MDNR dams. During the time when these dams impounded water, PCB-contaminated sediments were deposited in the impoundments. When the superstructures of these dams were removed in 1986 and the water level was lowered to the dam sill, most of the deposited contaminated sediments were exposed in the floodplain. These exposed sediments are continuously being eroded into the Kalamazoo River and constitute a continual source of PCBs to the river system. The largest acreage of exposed sediments is behind the Trowbridge Dam. Residential properties are found immediately adjacent to the exposed sediments behind the Trowbridge and Otsego Dams. In some areas, the gray paper residual waste can be observed in the backyards of residential homes along the river. Additionally, the construction of a golf course behind the Trowbridge impoundment occurred on top of and immediately adjacent to exposed sediments containing paper residual waste. Established gardens have been observed in the former impoundment area behind Otsego Dam.

These MDNR-owned dams, along with the Caulkins Dam impounding Lake Allegan, have been identified as areas where local anglers frequently catch fish in the Kalamazoo River. Attractive habitat for fish near the dams attracts the anglers observed fishing in these stream reaches. Some fishing locations have been established on exposed floodplain sediments. In addition to attracting anglers, the three MDNR impoundments also attract waterfowl hunters, as evidenced by the duck blinds observed in the backwaters behind the remaining dam structures.

Floodplain and river sediments are both transport and exposure media. That is, sediments (instream and floodplain) are continuously entrained in and deposited from the water column, causing redistribution of PCBs in the riverine system. Further, some PCBs may become dissolved in surface water or entrained in air. In addition, sediments are a source for PCBs in fish, turtles, and probably waterfowl, and a potential source of exposure to residents and recreationalists living near or visiting areas with exposed contaminated sediments. For purposes of this evaluation, residents who live near the exposed floodplain soils were considered the most highly exposed individuals for direct contact exposure pathways. Risk and hazard quotient estimates for these individuals will serve as a conservative representation of risks and hazards to individuals that frequent the river.

Exposure routes either directly to the river and floodplain soil, or to secondary exposure media (surface water and air), include ingestion, sediment or soil, and surface water; dermal contact with sediment or soil and surface water; and inhalation of particulates and/or vapor emissions from exposed sediments.

Importantly, sediments are also a source of PCBs in fish tissues. Anglers, both recreational and subsistence, may be exposed to significant levels of PCBs via ingestion of fish taken from contaminated reaches of the river. In many assessments of

PCB contamination in river systems, consumption of contaminated fish has resulted in the highest estimates of exposure and health risk. Significant further evaluation of possible exposure of anglers and their families is provided in a later subsection. In particular, the existence and potential for exposure for subsistence anglers is characterized in Section 3.3.1. Subsistence anglers are those individuals who derive a large portion of their total dietary protein from consumption of locally caught fish.

Recreational and subsistence anglers, recreational users of the river for purposes other than fishing, and residents who may live near or on the river, were considered in the HHRA. For each of the populations, an exposure scenario was developed. An exposure scenario defines a particular manner in which people are exposed to contamination. An example of an exposure scenario includes: 1) ingestion of fish by subsistence anglers; and 2) ingestion of, dermal contact with, and inhalation of particulates and vapors from floodplain soil by nearby residents. Some of the possible exposure scenarios for the API/PC/KR site were evaluated quantitatively, i.e., numerical estimates of cancer risks and noncancer hazards were developed. Some of the possible exposure scenarios were evaluated qualitatively, i.e., a discussion of the significance of a particular pathway or adequacy of the data to evaluate the pathway was provided.

3.2 Determination of Exposure Pathway Significance

Many exposure pathways exist at most sites with significant chemical contamination. However, only a subset of these pathways, in almost all cases, might result in estimated risks high enough to warrant action to reduce exposures. In the following subsections, exposure pathways at the API/PC/KR site are identified that could result in risks above levels of concern.

3.2.1 General Considerations

Researchers have investigated the role of various environmental pathways of exposure to contaminants in the Great Lakes. Several multimedia studies indicated that most cases of human exposure (80 to 90 percent) to chlorinated organic compounds occur through the food pathway. A more recent multimedia study supports these findings and indicates that the primary pathway of exposure to PCBs is from fish consumption (Birmingham, et al. 1989; Newhook, et al. 1988; Fitzgerald, et al. 1996). Pathways involving ingestion of biota including fish and waterfowl were determined to warrant quantitative evaluation for the API/PC/KR site. However, as discussed in Section 2, data are insufficient to support quantitative analysis of exposures and risks to hunters who take and ingest waterfowl from the API/PC/KR site. Potential human health impacts for the hunter population remains a potentially significant source of uncertainty in this risk assessment.

During hunting or fishing activities, contact with river surface water and sediment may occur. Contact with surface water and sediment may also occur during other recreational activities such as swimming and boating. In general, contact with

sediment and surface water does not result in significant risks or hazards. This assumption is consistent with the findings presented in *Health Consultation for Allied Paper/Portage Creek/Kalamazoo River* (MDCH 1997). In that document, it is stated that "moist sediments might adhere more strongly to skin than drier soil, but river water would tend to wash the sediments off before the soiled skin reaches the mouth or food." In addition, the quantity of water consumed during swimming has been estimated to be significantly less than that consumed when water is used for drinking water (50 milliliters/hour, which is a typical swimming event versus 2 liters/day) (EPA 1989, 1992). For this reason, the ingestion of surface water is not considered a significant pathway.

To confirm that contact with instream sediment and surface water would not result in significant risks or hazards for the API/PC/KR site, site data were compared to data from the Lower Fox River in Wisconsin. Exposure conditions at the two sites are very similar in that both sites have active recreational populations involved in fishing, hunting, and boating and residential populations living on or near the site. An HHRA conducted for the Lower Fox River evaluated numerous pathways and found that only the following four exposure pathways were associated with significant risks or hazards:

- Ingestion of fish by subsistence anglers
- Ingestion of fish by recreational anglers
- Ingestion of waterfowl by hunters
- Inhalation of contaminants in outdoor air from volatizing from surface water by nearby residents

Significant risk is defined by MDEQ as a level above a cancer risk threshold of 1 in 100,000 excess lifetime cancer risk, and significant hazard of noncancer adverse health effect is indicated by a hazard quotient greater than 1.0.

The first two of these pathways were quantitatively evaluated for the API/PC/KR site. Additional data are needed, however, to adequately evaluate ingestion of waterfowl by hunters and volatilization from surface water to outdoor air.

Exposure pathways involving direct contact with surface water and instream sediment, i.e., the recreational wader or swimmer, were not associated with significant risks or hazards for the Lower Fox River. Drinking water ingestion was evaluated for the Lower Fox River, but water from the Kalamazoo River is not used for drinking water; therefore, this pathway is not relevant to the site.

3.2.2 Quantitative Comparisons with Lower Fox River

Table 3-1 presents upper-bound and average concentrations of PCBs in sediment, surface water, fish, and waterfowl at the Lower Fox River and API/PC/KR sites.

Upper-bound and average concentrations for all abiotic and biotic media are higher from the API/PC/KR site than from the Lower Fox River site.

Relative risks and hazards for the two rivers can be estimated by scaling estimates for the Kalamazoo River using the Lower Fox River as a baseline. Scaling assumes that exposure assumptions for recreational swimmers, waders, sport anglers, and subsistence anglers are comparable at the two sites. These scaling assumptions are justified in the present case because of the substantial similarities of the two river environments.

Table 3-1 Comparison of Total PCB Exposure Point Concentrations of Lower Fox River and Kalamazoo River API/PC/KR Site

Medium	Upper Bound [1]		Central Tendency [2]	
	Fox River [3]	Kalamazoo [4]	Fox River [3]	Kalamazoo [4]
Fish Tissue (mg/kg) (Fillet data)	4.6 [6]	17.34 (max-carp) 5.8 (max-smb)	3.0 [6]	7.6 (carp) 1.9 (smb)
Waterfowl Tissue (mg/kg)	1.23 [7]	4.8 (max)	0.54	1.7
Surface Water (mg/L)	1.49E-04 [8]	7.1E-05 (max)	4.42E-05	2.5E-05 (median)
Sediment (mg/kg)	3.75 [9] 710 [12]	156 (max-ABSA 7) [10] 13.6 (U95, ABSA 7)	3.69 [11] 20 [12]	3.7 [5]

(1) Upper-bound measure concentrations - lower of the 95% UCL on the arithmetic mean or the maximum detected concentration.

(2) Central Tendency = the arithmetic mean except for Kalamazoo surface water which is median value.

(3) Lower Fox River data from ThermoRetec, 2001.

(4) Kalamazoo River data derived from following sources:
Fish (BB&L 1995b; 1998)
Waterfowl (MDNR 1987)
Surface Water (BB&L 1995a)
Sediment (BB&L 1994a)

(5) Average from ABSAs 3,4,5,6,7,8,9 as reported in CDM 1999 originally derived from BB&L 1994a.

(6) Upper-bound concentration is the maximum detected in fillet samples of walleye collected from the DePere to Green Bay reach in the 1990s. Central tendency concentration is average for carp collected in the same reach in the 1990s. The most common species sampled include walleye, carp, trout, and bass.

(7) Upper-bound concentration is the 95% UCL on the arithmetic mean of samples collected from Little Rapids to DePere reach.

(8) Upper-bound concentration is the 95% UCL on the arithmetic mean of surface water samples collected from the DePere to Green Bay reach. All water concentrations result from analyses of unfiltered samples.

(9) Upper-bound concentration is the 95% UCL on the arithmetic mean of samples collected from Little Lake Butte des Morts reach. Concentration is based on interpolated data. Note that some higher concentrations (710 max; 20 average mg/kg) were found in the DePere to Green Bay reach.

(10) For the Kalamazoo River site, ABSA 7 was chosen for the comparison because the maximum PCB concentration occurred in this reach of the river and because overall concentrations in this ABSA were relatively high. The average concentration in ABSA 7 (5.2 mg/kg) is about twice the sitewide average (2.4 mg/kg). Using ABSA 7 to represent the API/PC/KR site should provide a "worst case" for comparison with the Fox River.

(11) Highest average based on interpolated data from Little Lake Buttes des Morts reach.

(12) The higher value was calculated from the DePere to Green Bay reach.

When all exposure parameters for a population are held constant, risks and hazards are proportional to exposure concentrations. The ratio of media concentrations to risks or hazards for the Lower Fox can therefore be used to estimate risks or hazards associated with API/PC/KR media concentrations. Such scaled risks and hazards associated with exposure to upper-bound instream sediment and surface water are

shown in Table 3-2. Even though PCB concentrations for surface water and most instream sediment in API/PC/KR were higher than the Lower Fox, exposure involving contact with these media would not result in risks or hazards that exceeded regulatory thresholds. A more complete description of the results of risk and hazard scaling are presented in Appendix D.

Table 3-2 Comparison of Calculated Fox River and Scaled Kalamazoo River API/PC/KR Site Risks and Hazards

		Fox River		Kalamazoo River	
Pathway	**Media**	**Calculated Risks**	**Calculated Hazards**	**Scaled Risks**	**Scaled Hazards**
Recreational Angler	Surface Water	1.7E-08 - 1.2E-07 (1)	1.0E-03 - 6.0E-03 (1)	1.2E-07 - 3.5E-07 (2)	2.2E-03 - 2.9E-02 (2)
	(ingestion, dermal contact)				
Subsistence Angler	Surface Water	2.4E-08 - 1.6E-07 (1)	2.0E-03 - 8.0E-03 (1)	2.8E-08 - 4.7E-07 (2)	5.4E-02 - 3.9E-02 (2)
	(ingestion, dermal contact)				
Recreational Swimmer	Surface Water	6.8E-08 (3)	1.4E-02 (3)	2.0E-07 (4)	4.1E-02 (4)
	(ingestion, dermal contact)				
	Sediment	8.7E-08 (3)	2.5E-02 (3)	5.8E-08 - 2.1E-07 (5)	1.7E-02 - 6.2E-02 (5)
	(ingestion, dermal contact)				
Recreational Wader	Surface Water	7.8E-09 (3)	2.0E-03 (3)	2.3E-08 (4)	9.8E-03 (4)
	(ingestion, dermal contact)				
	Sediment	1.9E-07 (3)	2.5E-02 (3)	1.3E-07 - 4.7E-07 (5)	1.7E-02 - 6.2E-02 (5)
	(ingestion, dermal contact)				

Scaled risks are calculated as FOX RIVER - RISK OR HAZARD * API/PC/KR - MEDIA CONCENTRATION ÷ FOX RIVER - MEDIA CONCENTRATION

Notes:

(1) Based on range of calculated cancer and noncancer risks associated with the average concentration and the upper-bound concentration (either 95% UCL or maximum).

(2) Based on scaled cancer and noncancer risks associated with the average concentration and the maximum concentration.

(3) Based upper-bound concentrations (either on 95% UCL or maximum). Based on concentrations of PCBs in Little Lake Butte des Morts.

(4) Based on maximum concentrations.

(5) Based on range of calculated cancer and noncancer risks associated with the average concentration and the 95% UCL.

3.3 Receptors

Recent data compiled through the ATSDR Great Lakes program indicate the following:

- Approximately 4.7 million people consumed Great Lakes' sport-caught fish within the past year
- Knowledge of and adherence to health advisories for sport-caught fish vary across different populations
- Advisory awareness is especially low in women and minority populations

- Fish are an essential component of the diets of minority and Native American populations; they consume fish that tend to have higher levels of contaminants, and their cooking practices increase their exposure to Great Lakes contaminants compared to recommended fish preparation techniques (Johnson 1998)

Further for the API/PC/KR site,

- Residences abut former impoundment areas, and some gray residuals from paper wastes have been observed in residential yards

- Evidence of recreational use is observed in former impoundment areas; including established gardens, trails, hunting blinds, and fishing spots

The above information, combined with the pathways analysis presented in Section 3.2, indicates that five receptor groups should be quantitatively evaluated in this HHRA for one or more pathways of exposure, including:

- Subsistence anglers
- Central Tendency Sport anglers
- High end sport anglers
- Nearby residents
- Recreationalists

3.3.1 Subsistence Anglers

Subsistence anglers are individuals who would not be able to meet their daily nutritional requirements if they could not supplement their diet with sport-caught fish. In a survey financed by the Michigan Great Lakes Protection Fund, *Michigan Sport Anglers Fish Consumption Study*, 1991-1992 (West 1993), a sample of 7,000 persons with Michigan fishing licenses was drawn and surveys were mailed in 2-week cohorts from January 1991 to January 1992. Respondents were asked to report consumption patterns during the proceeding 7 days. A response rate of 46.8 percent was reported with 2,681 surveys returned. Fish consumption rates were found to be higher among minorities, people with low income, and people residing in small communities.

Three subpopulations of subsistence anglers have been evaluated in several studies of the Great Lakes region:

- Low-income/minorities
- Native Americans
- Hmong

Out of a total estimated population of 329,912 in Allegan and Kalamazoo counties, West (1993) estimated a low income (<$25,000) population of 99,094, and a minority/low-income population of 9,022.

The MDCH conducted the Kalamazoo River Angler Survey and Biological Testing Study. This study, funded by the ATSDR, involved field surveys conducted from May to September 1994 and interviews of 938 anglers in Kalamazoo and Allegan Counties. Information on income level was not reported, though unemployment rates were reported. Unemployment rates for anglers in Allegan County (20.5 percent) and Kalamazoo County (17.4 percent) were higher than the overall unemployment rates for these counties (MDCH 2000b). Respondents were questioned on age, education, race (white, nonwhite), gender, smoking status, drinking status, weight change, and awareness of fish advisories.

Almost 4 percent of the Allegan County anglers reported that they fished for food only, while none of the Kalamazoo County anglers reported that they fished for food only. An additional 10.6 percent of all anglers responded that they fished for both food and recreation (MDCH 1998).

Allegan and Kalamazoo County public health agency staff conducted the interviews. Interviewers reported they were unable to interview Hmong anglers that have been observed fishing in the Lake Allegan area. At other Superfund sites, this segment of the population makes up a large component of the subsistence fishing population. Two key studies, *Hmong Fishing Activity and Fish Consumption* (Hutchinson and Kraft 1994) and *Fish Consumption by Hmong Households in Sheboygan, Wisconsin* (Hutchinson 1994) examined fishing activity and fish consumption rates in Green Bay, Wisconsin and Sheboygan, Wisconsin, respectively.

Native American anglers were not specifically targeted in the Kalamazoo Angler Survey although an early draft of the survey reported that 9 percent of 143 male respondents in Allegan County were Native American and 0.5 percent of 213 male respondents in Kalamazoo County were Native American. A number of studies have been conducted on fish ingestion rates of Native American populations in Alaska (Wolfe and Walker 1987); the Columbia River Basin (CRITFC 1994); Wisconsin (Peterson, et. al 1994; Fiore 1989); and the St. Lawrence River (Fitzgerald 1995, 1996).

The Lower Fox River HHRA evaluated four different subsistence fishing scenarios:

- Low-income, minority (based on West 1993 data)
- Native American angler (based on Peterson 1994 and Fiore 1989)
- Hmong (based on Hutchinson and Kraft 1994)
- Hmong (based on Hutchinson 1998)

The overall ingestion rates and exposure frequencies for the low-income, minority angler were the highest of these four scenarios; risks and hazards for the low-income, minority angler were also the highest of these four scenarios. For this reason, and the existence of this subpopulation within and near the API/PC/KR site, the subsistence scenario used for the site is based on a low-income, minority population.

3.3.2 Sport Anglers

Fishing is a popular recreational activity on the Kalamazoo River. Because multimedia studies have indicated that most cases of human exposure to chlorinated organic compounds (80 to 90 percent) occur through the food pathway, and the primary pathway of exposure is from fish consumption, risks and hazards to the sport angler population were evaluated in this HHRA.

The Kalamazoo River is a favorite fishing site for sport anglers and subsistence fishermen. Smallmouth bass are a favorite target in the Kalamazoo area. Additionally, the downstream reaches of the Kalamazoo River below Caulkins Dam is known for steelhead and salmon fishing. The Kalamazoo River is also popular for catching carp, panfish, channel catfish, and sucker species (personal communication with Jim Dexter, MDNR).

Anglers have been observed fishing in the vicinity of the three MDNR dams on a regular basis, and the Trowbridge Dam has a boat launch ramp used by anglers and duck hunters to access the backwater areas behind this impoundment. Fishing is limited on Lake Allegan due to poor habitat, and most fishing is restricted to channel catfish, carp, and occasional panfish.

Two populations of sport anglers were evaluated to provide some indication of the possible range of exposures and risks. The central tendency sport angler was evaluated to provide an indication of average exposures in the angler population. The high end sport angler was evaluated to provide an upper-range estimate characteristic of avid sport anglers. Assumptions regarding fish ingestion rates, reduction of PCBs due to cooking fish, and portion of fish caught from the contaminated area are different for the central tendency and high end sport anglers. These assumptions are further discussed in Section 3.5.2.

3.3.3 Nearby Residents

Urban, suburban, and rural residential populations exist along stretches of the Kalamazoo River. Development within the 100-year floodplain is restricted; however, despite inclusion of 80 miles of the Kalamazoo River in the study area of the API/PC/KR National Priority List site, residential, commercial, and recreational development along the river outside this floodplain has proceeded unrestricted.

In particular, residential development has occurred adjacent to exposed floodplain soil in the vicinity of the former Trowbridge, Otsego, and Plainwell dams. These areas are completely accessible to the public and, in essence, form the "backyard" for some residents. For these reasons, a residential scenario was evaluated for direct exposure in the three floodplain areas.

3.3.4 Recreationalists

Some parts of the former impounded areas abut neighborhoods and residential property and are completely accessible to children and adults. Other areas are relatively less accessible to children but are accessible to adults who may engage in recreational activities such as bird watching, picnicking, and hunting. In particular, the former impoundment areas near the Trowbridge, Otsego, and Plainwell Dams are accessible for these activities and are large enough to attract frequent visitors. For these reasons, a recreational scenario was evaluated for direct exposure in the floodplain areas.

3.4 Exposure Pathways Summary

Figure 3-1 presents a site conceptual model for the API/PC/KR site. The conceptual model identifies potential receptors and exposure pathways. The model is a graphic summary to the preceding pathways and receptor analyses.

As discussed above, exposure pathways are the mechanisms by which people are exposed to chemicals from a site. A pathway is the route between a contaminated medium and a receptor. Some exposure pathways were evaluated qualitatively; i.e., a discussion of the relative insignificance of these pathways was provided to support eliminating them from further consideration. Some pathways were evaluated quantitatively; i.e., numerical estimates of cancer risks and noncancer hazards were generated. Receptors and exposure pathways quantitatively evaluated for this site include:

- Sport anglers - fish ingestion
- Subsistence anglers - fish ingestion
- Residents living adjacent to exposed floodplain soil - incidental ingestion of, dermal contact with, and inhalation of particles and the volatile fractions of floodplain soil
- Recreationalists exposed to floodplain soil - incidental ingestion of, dermal contact with, and inhalation of particles and the volatile fractions of floodplain soil

The Kalamazoo River is used for swimming, boating, and fishing. While a fish consumption advisory has been issued by the MDCH, the advisory is not legally binding, and local health officials and other local government representatives reported observing frequent fishing activity within the contaminated zone of the river (MDCH 1999). Subsistence level consumption of fish from the river cannot be ruled out.

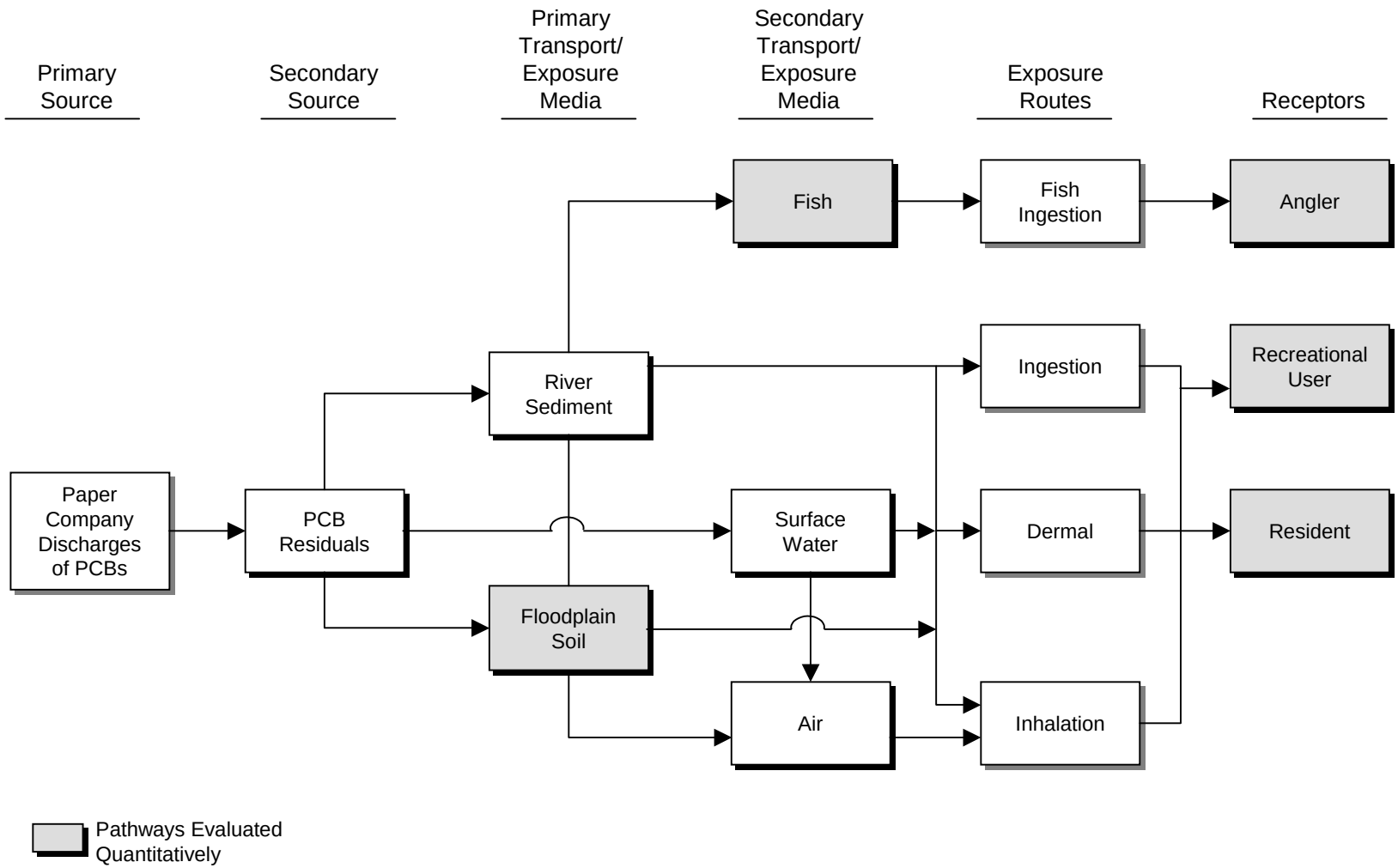

Figure 3-1
Site Conceptual Model
API/PC/KR Site

CDM

Fish ingestion is the primary exposure pathway for the API/PC/KR site. PCBs bioaccumulate in the food chain. Ingestion of fish is likely to result in higher exposures and greater risks than direct exposures to sediment and surface water containing PCBs. Exposure to floodplain soils is also considered to be significant, and was evaluated quantitatively due to the close proximity of residential areas to the floodplain soils.

Residents live immediately adjacent to former impoundment areas and may frequently use these areas much as other residents use their backyards. For example, large, well-maintained vegetable gardens have been found in the impoundments. Further, gray paper waste residual materials have been observed in residential yards, suggesting that exposures could take place in some areas outside the floodplain.

The recreational user of the river is likely exposed to instream sediment and surface water during swimming or wading activities or to floodplain soil, including soils near the three former MDNR impoundments, during other recreational activities.

A number of recreational activities are undertaken along the Kalamazoo River including hunting, picnicking, mushroom and berry picking, and bird watching. Hunting seasons for the following animals draw recreationalists to the banks of the Kalamazoo from September through May: rabbit (September 15 through March 31); deer (archery: October 1 through November 14; firearm: November 15 through 30; muzzle-loading: December 10 through 19); grouse (September 15 through November 14 and December 1 through January 1); squirrel (September 15 through January 1); turkey (October 4 through November 9 and April 12 through May 31); woodcock (September 25 through November 8); fox (October 15 through March 1) and raccoon (October 1 through January 31). Exposure to floodplain soil is considered significant for both nearby residents and recreationalists, therefore recreational exposures to floodplain soils was evaluated quantitatively.

The significance of exposures to instream sediment and surface water is considered low due to the relatively low surface water and sediment ingestion rates associated with swimming and wading, the low solubility of PCBs in water, and limited absorption through the skin.

Two exposure pathways have not been fully evaluated in this HHRA due to a lack of data. The Kalamazoo River watershed area is used extensively to hunt duck and other waterfowl. A limited and potentially outdated data set exists to quantitatively evaluate this pathway. It is recommended that additional data be collected to determine the potential risks to hunters who ingest duck and other waterfowl.

Volatilization of PCBs from surface water to air has been evaluated in previous risk assessments conducted on sites similar to the API/PC/KR. In the *Baseline Human Health and Ecological Risk Assessment for the Lower Fox River, Wisconsin* (ThermoRetec Consulting Corporation 1999), risk estimates for this exposure pathway were above the EPA risk thresholds. Maximum and average concentrations in the Kalamazoo

River are higher than those detected in the Fox River, indicating that risks may be higher for the API/PC/KR site. This pathway may be evaluated in an addendum to this HHRA.

3.5 Exposure Assumptions

To estimate risks and hazards to populations, the magnitude and nature of exposures to chemicals must first be characterized. Information and assumptions on frequency of exposure, duration of exposure, and consumption rates are used to estimate exposures received by people who eat contaminated fish or who live, work, or play on contaminated soils. These exposure assumptions result from the evaluation of surveys and studies conducted on the behaviors of individuals and groups such as subsistence and sport anglers, and residents. Some exposure assumptions are also based on EPA and MDEQ guidance.

3.5.1 Generalized Assumptions

Tables 3-3, 3-4, and 3-5 summarize the exposure assumptions for sport and subsistence anglers, residents near floodplain soil, and recreationalists respectively. Many exposure assumptions for anglers are taken from the results of angler surveys specific to the Kalamazoo River area. These assumptions are discussed in more detail in Section 3.5.2. Many other assumptions are more generic and are adopted from regulatory guidance. Exposure assumptions for exposure frequency and duration from recreational exposures are based on professional judgment.

Body weight is a standard exposure factor for adult males specified in the Exposure Factors Handbook (EPA 1997). Soil ingestion rate, dermal contact rate, and inhalation rate are age-adjusted rates for individuals from 1 to 31 years of age. These exposure assumptions, along with exposure frequency and duration for residential exposures, are given as standard default assumptions for the residential scenario in Environmental Response Division Interim Operational Memorandum #18: Generic Soil Direct Contact Criteria (MDEQ 2000). Ingestion of soil by nearby residents is assumed to take place year-round because soil from outdoor sources can be entrained into the indoor environment as indoor dust.

Ingestion of soil by recreationalists is assumed to occur only on days when they are on the site. Dermal exposure is limited to periods during which there is no snow cover preventing contact (MDNR 1995). The number of days of exposure per year is based on the assumption that recreational exposure will be frequent because of the proximity of recreational and residential areas. The number of years of exposure is based on a typical upper-range estimate of time at one residence (EPA 1997), reduced to exclude the youngest children who are not expected to wander far from their yards on a regular basis.

Table 3-3 Exposure Assumptions for Sport and Subsistence Anglers API/PC/KR Site

Assumption	Central Tendency Sport Angler	High End Sport Angler	Subsistence Angler	Reference
Body Weight	70-kg	70-kg	70-kg	EPA 1997
Fish Ingestion Rate	0.015 kg/day (24 meals/year)	0.078 kg/day 125 meals/year	0.11 kg/day (179 meals/year)	West 1993
Fraction from Contaminated Source	1.0	0.5	1.0	Site-Specific
Exposure Frequency	365 days/year	365 days/year	365 days/year	EPA 1997
Exposure Duration	30 years (cancer) 30 years (noncancer) 2-7 years (reproductive)	30 years (cancer) 30 years (noncancer) 2-7 years (reproductive)	30 years (cancer) 30 years (noncancer) 2-7 years (reproductive)	EPA
Species	Smallmouth bass (100%) and Smallmouth bass/Carp (76%) (24%)	Smallmouth bass (100%) and Smallmouth bass/Carp (76%) (24%)	Smallmouth bass (100%) And Smallmouth bass/Carp (76%) (24%)	Site-Specific
Reduction Factor	50%	50%	50%	Zabik 1995
Relative Absorption Efficiency	100%	100%	100%	ATSDR 1996

Table 3-4 Exposure Assumptions for Residents Near Floodplains Soils API/PC/KR Site

Assumption	Resident	Reference
Soil Ingestion	114 mg-yr/kg-day (age adjusted)	MDNR 1995
Dermal Contact Rate	353 mg-yr/kg-day (age adjusted)	MDEQ 2000
Inhalation Rate	7.52 m3-yr/kg-day (age adjusted)	MDNR 1995
Age	1-31 years	EPA 1997
Fraction from Contaminated Source	1.0	Site-Specific
Exposure Frequency	350 days/year (ingestion) 245 days/year (dermal)	MDNR 1995
Exposure Duration	30 years (cancer) 30 years (noncancer) 2-7 years (reproductive)	EPA 1997
Relative Absorption Efficiency	0.14	EPA 1998a

Table 3-5 Exposure Assumptions for Recreationalists on Floodplain Soil

Assumption	Resident	Reference
Soil Ingestion	2.8 mg-yr/kg-day 47 mg-yr/kg-day 34 mg-yr/kg-day	MDNR 1995
Dermal Contact Rate	85 mg-yr/kg-day 61 mg-yr/kg-day	EPA 1997b
Inhalation Rate	1.37 m3-yr/kg-day 1.9 m3-yr/kg-day	EPA 1997b
Age	6 - 31 years	Site-Specific
Fraction from Contaminated Source	1.0	Site-Specific
Exposure Frequency	128 days	Site-Specific
Exposure Duration	2-7 years (reproductive) 24 years (immunological) 24 years (cancer)	EPA 1997b EPA 1997b EPA 1996
Relative Absorption Efficiency	0.14	EPA 1998

For reproductive effects, an exposure duration of 2 to 7 years is used based on toxicity studies that indicate adverse effects on the fetus such as reduced birth weight, reduction in gestational age, and reduced head circumference. Two to seven years is a conservative estimate based on an assumption that continuing exposure over a fairly short time period leading up to conception could result in toxic levels of PCBs in the developing embryo/fetus. In practice, the exposure duration term for noncancer health effects appears in both the numerator and denominator of exposure equations. Thus, when all other parameters are kept constant, changing the exposure duration does not alter hazard estimates. The short exposure duration assumption therefore reflects a qualitative judgment of potential for health effects and does not affect calculated hazards. Section 4 of this report describes the toxicity of PCBs in more detail.

For recreationalists, unitized contact rates are not provided in MDEQ guidance. Soil ingestion for the recreationalist is based on 100 milligrams ingestion for each day of exposure. The unitized ingestion rate is derived as follows:

100 mg / day * exposure duration / 70 kilograms bodyweight

The dermal contact rate for recreationalists assumes exposures of the face, forearms, and hands and a soil adherence factor of 0.07 (MDNR 1995). The unitized dermal contact rate is derived as follows:

2,572 cm^2 * 0.07 * exposure duration / 70 kilograms bodyweight

The inhalation rate for recreationalists assumes an hourly inhalation rate for moderate activities of 1.0 m^3 (EPA 1997). The unitized inhalation rate is derived as follows:

1.0 m^3 /hour * 4 hours/day * exposure duration / 70 kilograms bodyweight

An exposure time of 4 hours per day is based on professional judgment. Additional details on the derivation of these assumptions are presented in Section 3.5.2.

3.5.2 Specific Exposure Assumptions

3.5.2.1 Fish Ingestion Rates

A key factor in assessing the risks and hazards associated with ingestion of sport-caught or subsistence-caught fish is the ingestion rates of the sport and subsistence anglers. Two key studies of fish ingestion behaviors of anglers in the Great Lakes region were conducted by Patrick West of the University of Michigan: Michigan Sport Anglers Fish Consumption Survey (1989) and Michigan Sport Anglers Fish Consumption Study (1993). In 1989, West surveyed a stratified random sample of Michigan residents with fishing licenses. Each of 18 cohorts received a questionnaire 1 week apart between January and May 1989. The survey included both a "short-term recall" component and a "usual frequency" component. The respondents were also asked to recall serving size based on comparison with a picture of a cooked 8-ounce fish portion. A total of 2,334 survey questionnaires were delivered and 1,104 were completed and returned giving a 47.3 response rate. Average fish consumption by age group, education level, place, and years of residence were reported. Because the study was conducted in the winter and spring when fishing activity may be relatively low, it may underestimate fish ingestion rates, even though respondents were asked to recall year-round consumption rates.

In 1993, a follow-up survey was conducted by West. A total of 7,000 survey questionnaires were delivered and 2,681 were completed and returned. A response rate of 46.8 was calculated by removing those respondents who could not be located or who had not resided in Michigan for at least 6 months. Estimates of fish consumption were reported by minority status and income status (low-income or non-low-income) for both sport and commercial fish. Respondents were also surveyed on education, species targeted, and cooking methods. The survey period extended for a year, covering all four seasons. The strengths of both of these surveys are sample size and reliance on short-term recall (EPA 1995c).

Minority, low-income respondents were reported to have the highest ingestion rates followed by nonminority low-income respondents. The 95th percentile ingestion rates for minority, low income (109 grams / person / day) and nonminority low-income (78 grams / person / day) respondents were used to represent subsistence and high end sport angler ingestion rates. Ingestion rates are normalized over a 365-day period by multiplying the number of fish meals by the serving size and dividing by 365 days / year. A typical serving size of 8 ounces (225 grams) is used (EPA 1996).

EPA has conducted a statistical validation of the West data showing strong correlation between 7 day recall ingestion rates and long-term recall ingestion rates (EPA 1995b). The Kalamazoo River survey may have resulted in a bias toward populations who only fished during daylight hours when the survey was conducted. The lack of interview data from Hmong anglers has been previously noted and may present a deficiency regarding subsistence fishing patterns. Responses to questions regarding catch and release practices resulted in some apparent inconsistent responses. When asked if they practice "catch and release" only, 73.5 percent of

respondents answered yes, although a total of 44 percent also reported eating fish from the Kalamazoo River and / or Portage Creek. *The Kalamazoo River Angler Survey and Biological Testing Study* (MDCH 1998) was conducted to determine the utilization of the affected portions of Portage Creek and the Kalamazoo River by sport anglers or other persons who regularly eat fish from these waters. Face to face interviews were conducted with 938 individuals in Kalamazoo and Allegan Counties. Fish ingestion rates by age, education, race, gender, smoking, and drinking status were reported. About 75 percent of anglers surveyed reported they eat fish from the river no more than one meal per month (7 grams / person / day). Slightly more than 10 percent reported eating fish more often than one meal per week (32 to 65 grams / person / day). The mean ingestion rate for sport anglers was reported as 24 meals / year.

A second Kalamazoo River Angler Survey was conducted by Dr. Charles Atkin of Michigan State University (Atkin 1994). The survey was conducted via long-distance telephone interviews and included 690 respondents. Interviews were conducted in six counties: Allegan, Barry, Calhoun, Eaton, Kalamazoo, and Ottawa. Thirty-three percent of the study participants were from Kalamazoo and Allegan Counties. While the study's applicability to this HHRA is limited by the fact that less than a dozen people from Kalamazoo County and less than 50 people from Allegan County (the two counties within the KRSS) were actually asked which fish were eaten, and questions exist regarding validity of questions, answers, or data entry, several of the conclusions of the study support the use of a number of assumptions in the HHRA:

- Those who consume fish eat an average of 2.6 meals per week, slightly higher than the 2.4 meals per week used for the sport angler (high end) in the HHRA.

- Average serving size was 8.66 ounces, higher than the 8 ounce assumption used in the HHRA.

- Six percent of those surveyed overall indicated they eat bottom-feeding fish, lending additional support to include a representative bottom-feeder in the HHRA. Regarding consumption of bottom feeders, a slightly greater percentage of participants in Kalamazoo and Allegan Counties, compared to the study group overall, indicated they consume carp, catfish, and suckers.

- Thirty percent of those eating bottom feeding fish reported they sometimes or never remove or puncture the skin and 30 percent of those eating fish reported they sometimes or never trim fat from fish. These results suggest that the reduction factor used to account for trimming and cooking practices may represent more of an average than a high end value. Reduction in PCB exposure due to trimming and cooking may be higher than assumed in this assessment for relatively large number of anglers in the area.

The *Great Lakes Water Quality Initiative Technical Support Document for Human Health Criteria and Values* (EPA 1995) reports a 15 grams / person / day ingestion rate as the mean value for sport anglers in the Great Lakes Basin and as the 90th percentile for

the overall population in the Basin. The value of 15 grams / person / day was derived from a review of several regional studies in Michigan, (West 1989, 1993) Wisconsin (Fiore, et al. 1989), and New York (Connelly, et al. 1990). This fish ingestion rate is used by the MDEQ Surface Water Quality Division to establish surface water quality standards. The 15 grams is divided into the grams of trophic level 3 fish consumed (3.6 grams) and the grams of trophic level 4 fish consumed (11.4 grams) as reported in the West, et al. (1993) survey. This value is also consistent with the Kalamazoo River Angler Survey (MDCH 2000), which reports a mean value for sport anglers of 24 meals / year (24 meals / year * 8 ounces / meal * 28.3 grams / ounce ÷ 1 year / 365 days = 15 grams / person / day).

3.5.2.2 Species Consumed

Four species of fish were collected from the API / PC / KR during the Biota Investigation: carp, smallmouth bass, sucker, and golden redhorse. Carp and smallmouth bass were targeted as bottom dwelling fish and sport fish respectively, and representative data from analysis of fillets was available for both species. The following species were reportedly consumed by Kalamazoo River Angler Survey respondents: catfish (83.6 percent); bass (69 percent); panfish (63 percent); walleye (46 percent); bullheads (29.9 percent); carp (27 percent); and suckers (13 percent). West reported 48 percent of individuals consumed smallmouth bass and 7 percent consumed carp. In terms of species consumed, the West data are considered less reliable than the Kalamazoo River Survey because the water bodies covered included fish species not found or not prevalent in the Kalamazoo River.

Two scenarios were evaluated for both sport and subsistence anglers: 1) ingestion of 100 percent smallmouth bass; and 2) ingestion of a combination of 76 percent bass and 24 percent carp based on the percentage of trophic level 3 fish (carp) and trophic level 4 fish (smallmouth bass) reported to be consumed (West 1993). For the first scenario, exposure concentrations were based solely on smallmouth bass data collected from the site. For the second scenario, a combination of smallmouth bass and carp data were used. Total ingestion rates were apportioned across the two species accordingly. Skin-on data were used for bass and skin-off data were used for carp. Skin-on or skin-off reflects preferences found for preparation methods among anglers (West 1993).

3.5.2.3 Reduction Factors

Fish advisories typically include recommendations on trimming and cooking fish that can result in a reduction in the delivered dose of a chemical. The 2000 Michigan Fish Advisory includes the following recommendations:

- Trim fatty areas (removal of the skin, belly fat, lateral, and dorsal fat).
- Remove or puncture skin before cooking allowing the fat to drain off.
- Cook so fat drips away. Bake, broil, or grill on a rack, or poach and do not use the liquid.

- Deep-fry trimmed fillets in vegetable oil.
- Do not pan-fry in butter or animal fat, and do not make fish soups or chowder.

The advisory states that a reduction of 50 percent of the contaminants in fish can be eliminated by following these practices.

In *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (GLFATF 1993), the effects of trimming and cooking are discussed. Fish that contain high concentrations of lipids are likely to have higher concentrations of lipophilic chemicals, such as PCBs. Removal of the fatty portions of fish will reduce the overall ingestion of PCBs. Cooking typically reduces a 1/2-pound raw sample to 1/3-pound cooked weight. The Protocol reports that the contaminant concentration (on a mg/kg basis) after cooking was most often the same as before cooking, though due to the reduced size of the sample, total delivered dose would be lower.

Data reported in the Kalamazoo River Angler Survey indicate that 35 percent of anglers leave the skin on fish prior to cooking. Based on data reported by ethnicity in the 1991-1992 Michigan Sport Anglers Study, between 44 and 84 percent of minority respondents reported not trimming fat from sport fish prior to cooking. Between 23 and 40 percent reported not removing skin prior to cooking. The most popular method of cooking was reported to be pan frying by 56 percent of anglers.

Based on a review of the preparation and cooking practices reported in the Kalamazoo River Angler Survey, the Michigan Anglers Survey, and the Great Lakes Protocol, a cooking reduction factor of 50 percent was incorporated into the equations used to estimate risks and hazards for the high end sport angler and the subsistence angler. No additional reduction was assumed to result from trimming, given the practices reported in the angler surveys. In a study by Zabik and others (Zabik 1995), pesticides and total PCBs were determined in raw and cooked skin-on and skin-off chinook salmon harvested from Lakes Huron and Michigan, as well as in carp fillets harvested from Lakes Erie and Huron. The effects of baking, charbroiling, and canning salmon and pan and deep fat frying carp on contaminant loss were measured. Average losses of total PCBs for carp ranged from 30 to 35 percent (Zabik 1995). A 22 percent reduction in PCBs, expressed as micrograms per fillet in raw and pan fried skin-on carp fillets, was reported. While a 50 percent reduction factor is not in the upper range of probable values for the site, it is a reasonable estimate. Protective exposure estimates can be based on a mix of upper-range and average assumptions (EPA 1997). Using a reduction factor of 50 percent is not likely to cause substantial underestimation of possible exposures.

3.5.2.4 Fraction from Contaminated Source

The high end sport anglers were assumed to frequent different locations to fish. Some of these locations may include water bodies other than the Kalamazoo River. Fifty percent of their total fish ingestion was assumed to come from the API/PC/KR site.

Within the site, it is also possible to fish from different ABSAs, though average risks and hazards would not vary significantly depending on location within the site because detected fish concentrations are relatively consistent from ABSAs 3 through 11.

To be consistent with the MDEQ Surface Water Quality Division, the fraction of exposure from the API/PC/KR site was assumed to be 100 percent for the central tendency angler.

The subsistence angler population was assumed to be more likely to fish from one area. A low-income population may not have ready access to transportation that would allow them to travel to different areas to fish. The fraction of exposure from the API/PC/KR site was also assumed to be 100 percent for the subsistence angler population.

Nearby residents and recreationalists were assumed to receive 100 percent of their exposure to soil from the floodplain soil on days when exposure occurred.

3.5.3 Exposure Point Concentrations

Average and maximum concentrations were used to reflect a range of exposure point concentrations for the angler and nearby resident scenarios. These concentrations are presented on Tables 2-1 and 2-3.

3.5.4 Intake Equations

The intake or dose from the ingestion of fish is calculated using the equation presented on Figure 3-2 (EPA 1989). The equation for intake or dose from the ingestion, dermal, and inhalation of floodplain soil is presented in Figure 3-3 (MDEQ 1995). The values for the variables in these equations are discussed above in Section 3.5.2. Note that EPA equations do not generally present unitized contact rates for soil ingestion, dermal contact, and inhalation rates. Unitized rates, however, are simply combinations of basic parameters such as ingestion and inhalation rates, body surface area, exposure duration, and body weight. All of these parameters are included in standard EPA equations. Thus, equations in Figures 3-2 and 3-3 are exact equivalents of those presented in EPA (1997c).

Figure 3-2
Formula used for The Calculation of Intake
Fish Ingestion

$$I = \frac{C * RF * IR * FI * EF * ED}{BW * AT}$$

Where:

I	=	Intake (mg / kg-day)
C	=	Concentration in Raw Fish Filet (mg / kg) [1]
RF	=	Reduction Factor (unitless)
IR	=	Ingestion Rate (kg / day)
FI	=	Fraction Ingested (unitless)
EF	=	Exposure Frequency (days / year)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (days)

[1] Intakes were estimated using both average and maximum fish tissue concentrations.

Figure 3-3
Formula used for The Calculation of Intake
Floodplain Soils - Ingestion / Dermal Contact / Inhalation

$$I = C * FC \left[\frac{(EF_i * IR_{soil} * AE_i) + (EF_d * DF * AE_d) + (EF_{inhal} * IR_{air} * AE_{inhal} (VF + PEF))}{AT * CF} \right]$$

Where:

I	=	Intake (mg / kg-day)
C	=	Concentration in Soil (µg / kg)
FC	=	Fraction of Soil Contaminated (unitless)
IR_{soil}	=	Ingestion Rate (Soil) (mg-yr / kg-day)
DF	=	Dermal Factor (mg-yr / kg-day)
IR_{air}	=	Inhalation Rate (Air) (m^3-yr / kg-day / day)
EF_i	=	Exposure Frequency (Ingestion) (days / year)
EF_d	=	Exposure Frequency (Dermal) (days / year)
EF_{inhal}	=	Exposure Frequency (Inhalation) (days / year)
AEi	=	Absorption Efficiency (Ingestion) (unitless)
AEd	=	Absorption Efficiency (Dermal) (unitless)
AE_{inhal}	=	Absorption Efficiency (Inhalation) (unitless)
VF	=	Soil to Air Volatilization Factor (mg / m^3-air / mg / kg-soil)
PEF	=	Particulate Emission Factor (mg / m^3-air / mg / kg-soil)
AT	=	Averaging Time (days)
CF	=	Conversion Factor (µg / kg)